# APPENDIX 10A. RELATIVE PRICE ELASTICITY OF DEMAND FOR APPLIANCES

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# APPENDIX 10A. RELATIVE PRICE ELASTICITY OF DEMAND FOR APPLIANCES

## 10A.1 INTRODUCTION

This appendix summarizes DOE's study of the price elasticity of demand for home appliances, including refrigerators, clothes washers and dishwashers. DOE chose this particular set of appliances because of the availability of data to determine a price elasticity. This appendix begins with a review of the existing economics literature describing the impact of economic variables on the sale of durable goods in section 9A.2. In section 9A.3, the market for home appliances and changes in it over the past 20 years is described. In section 9A.4, DOE summarizes the results of its regression analysis and presents estimates of the price elasticity of demand for the three appliances. In section 9A.5, DOE presents development of an 'effective' purchase price elasticity. DOE's interpretation of its results is presented in section 9A.6. Finally, section 9A.7 describes the data used in DOE's analysis.

## 10A.2 LITERATURE REVIEW

There are relatively few studies measuring the impact of price, income and efficiency on the sale of household appliances. In this section DOE provides a short review of this literature which suggests the likely importance of these variables.

### 10A.2.1 Price

The goal of many of the studies covered in this review is to measure the impact of price on sales in a dynamic market. One study of the automobile market prior to 1970 finds the price elasticity of demand to decline over time. The author explains this as the result of buyers delaying purchases after a price increase but eventually making the purchase (Table 9A.2.1).[1] A contrasting study of household white goods also prior to 1970, finds the elasticity of demand to increase over time as more price-conscious buyers enter the market.[2] A recent analysis of refrigerator market survey data finds that consumer purchase probability decreases with survey asking price.[3] Estimates of the price elasticity of demand for different brands of the same product tend to vary. A review of 41 studies of the impact of price on market share found the average price elasticity to be -1.75.[4] The average estimate of price elasticity of demand reported in these studies is -0.33 in the appliance market and -0.47 in the combined automobile and appliance markets.

### 10A.2.2 Income

Higher income households are more likely to own household appliances.[5] The impact of income on appliance shipments is explored in two econometric studies of the automobile and appliance markets.[1,2] The average income elasticity of demand is 0.50 in the appliance study cited in the literature review, much larger in the automobile study (Table 9.A.2.1).

### 10A.2.3 Appliance Efficiency and Discount Rates

Many studies estimate the impact of appliance efficiency on consumer appliance choice. Typically, this impact is summarized by the implicit discount rate, i.e., the rate consumers use to compare future appliance operating cost savings against an appliance purchase price premium. One early and much cited study concludes that consumers use a 20 percent implicit discount rate when purchasing room air conditioners (Table 9A.2.1).[6] A survey of several studies of different appliances suggests that the consumer implicit discount rate has a broad range and averages about 37 percent.[7]

**Table 10A.2.1 Estimates of the Impact of Price, Income and Efficiency on Automobile and Appliance Sales**

| Durable Good | Price Elasticity | Income Elasticity | Brand Price Elasticity | Implicit Discount Rate | Model | Data Years | Time Period |
|---|---|---|---|---|---|---|---|
| Automobiles[1] | -1.07 | 3.08 | - | - | Linear Regression, stock adjustment | - | Short run |
| Automobiles[1] | -0.36 | 1.02 | - | - | Linear Regression, stock adjustment | - | Long run |
| Clothes Dryers[2] | -0.14 | 0.26 | - | - | Cobb-Douglas, diffusion | 1947-1961 | Mixed |
| Room Air Conditioners[2] | -0.37[8] | 0.45 | - | - | Cobb-Douglas, diffusion | 1946-1962 | Mixed |
| Dishwashers[2] | -0.42 | 0.79 | - | - | Cobb-Douglas, diffusion | 1947-1968 | Mixed |
| Refrigerators[3] | -0.37 | - | - | 39% | Logit probability, survey data | 1997 | Short run |
| Various[4] | - | - | -1.76[9] | - | Multiplicative regression | - | Mixed |
| Room Air Conditioners[5] | - | - | -1.72 | - | Non-linear diffusion | 1949-1961 | Short run |
| Clothes Dryers[5] | - | - | -1.32 | - | Non-linear diffusion | 1963-1970 | Short run |
| Room Air Conditioners[6] | - | - | - | 20% | Qualitative choice, survey data | - | - |
| Household Appliances[7] | - | - | - | 37%[10] | Assorted | - | - |

**Sources:** [1] S. Hymens. 1971; [2] P. Golder and G. Tellis, 1998; [3] D. Revelt and K. Train, 1997; [4] G. Tellis, 1988; [5] D. Jain and R. Rao; [6] J. Hausman; [7] K. Train, 1985.

**Notes:** [8] Logit probability results are not directly comparable to other elasticity estimates in this table.
[9] Average brand price elasticity across 41 studies.
[10] Averaged across several household appliance studies referenced in this work.

## 10A.3 VARIABLES DESCRIBING THE MARKET FOR REFRIGERATORS, CLOTHES WASHERS, AND DISHWASHERS

In this section DOE evaluates variables that appear to account for refrigerator, clothes washer and dishwasher shipments, including physical household/appliance variables, and economic variables.

### 10A.3.4 Physical Household/Appliance Variables

Several variables influence the sale of refrigerators, clothes washers and dishwashers. The most important for explaining appliance sales trends are the annual number of new households formed (housing starts) and the number of appliances reaching the end of their operating life (replacements). Housing starts influence sales because new homes are often provided with, or soon receive, new appliances, including dishwashers and refrigerators. Replacements are correlated with sales because new appliances are typically purchased when old ones wear out. In principle, if households maintain a fixed number of appliances, shipments should equal housing starts plus appliance replacements.

### 10A.3.5 Economic variables

Appliance price, appliance operating cost and household income are important economic variables affecting shipments. Low prices and costs encourage household appliance purchases and a rise in income increases householder ability to purchase appliances. In principle, changes in economic variables should explain changes in the number of appliances per household.

During the 1980–2002 study period, annual shipments grew 69 percent for clothes washers, 81 percent for refrigerators and 105 percent for dishwashers (Table 9A.3.1). This rising shipments trend is explained in part by housing starts, which increased 6 percent and by appliance replacements, which rose between 49 percent and 90 percent, depending on the appliance, over the period (Table 9A.3.1).[a] For mature markets such as these, replacements exceed appliance sales associated with new housing construction.

**Table 10A.3.1 Physical Household/Appliance Variables**

| | Shipments[1] (millions) | | | Housing Starts[2] (millions) | | | Replacements[3] (millions) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Appliance** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** |
| Refrigerators | 5.124 | 9.264 | 81% | 1.723 | 1.822 | 6% | 3.93 | 5.84 | 49% |
| Clothes Washers | 4.426 | 7.492 | 69% | 1.723 | 1.822 | 6% | 3.66 | 5.50 | 50% |
| Dishwashers | 2.738 | 5.605 | 105% | 1.723 | 1.822 | 6% | 1.99 | 3.79 | 90% |

[1]Shipments: Number of units sold. **Sources:** AHAM Fact Book and Appliance Magazine.

[2]Housing Starts: Annual number of new homes constructed. **Source:** U.S. Census.

[3]Replacements: Average of annual lagged shipments, with lag equal to expected appliance operating life, ± 5 years.

Nevertheless, it is apparent that appliance shipments increased somewhat more rapidly than housing starts and replacements. This is shown by comparing the beginning and end points of lines representing "starts plus replacements" (uppermost solid line in Figure 9A.3.1) and "shipments" (diamond linked line in Figure 9A.3.1). In 1980 the "shipment" line begins below the "starts plus replacements" line. In 2002, the "shipments" line ends above the "starts plus replacements" line. This more rapid increase in shipments, compared to housing starts plus replacements, suggests that the appliance per household ratio increased over the study period.

[a] Appliance replacements are determined from the expected operating life of refrigerators (19 years), clothes washers (14 years), and dishwashers (12 years) and from past shipments. Replacements are further discussed in section 9A.3.

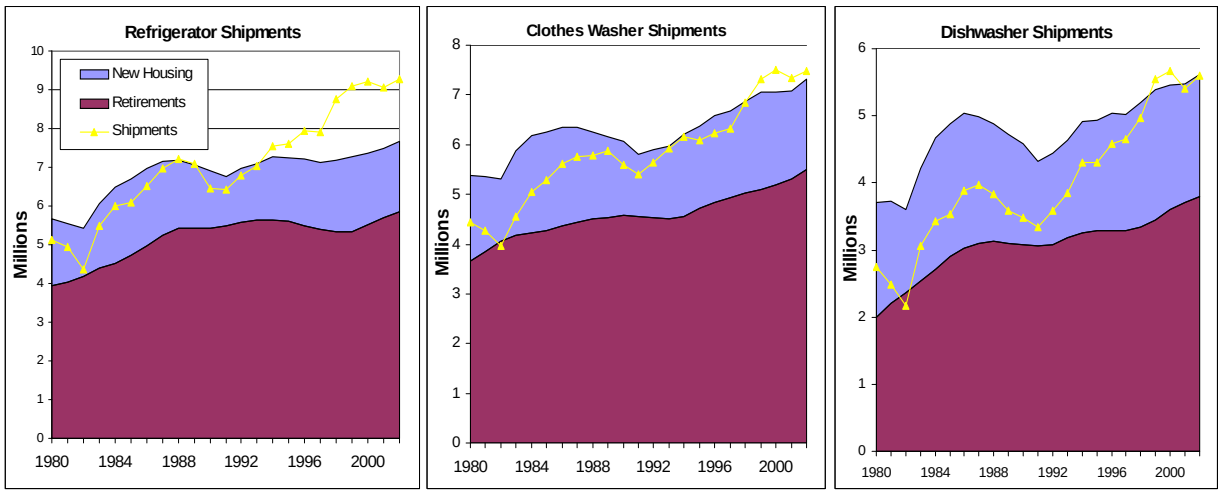


**Figure 10A.3.1 Trends in Appliance Shipment, Housing Starts and Replacements**

Economic variables, including price, cost and income, may explain this increase in appliances per household. Over the period, appliance prices decreased 40 percent to 50 percent, operating costs fell between 33 percent and 72 percent, and median household income rose 16 percent (Table 9A.3.2).

**Table 10A.3.2 Economic Variables**

| | Price[1] (1999$) | | | Operating Cost[2] (1999$) | | | Household Income[3] (1999$) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Appliance** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** |
| Refrigerators | 1208 | 726 | -40% | 333 | 94 | -72% | 37,447 | 43,381 | 16% |
| Clothes Washers | 779 | 392 | -50% | 262 | 175 | -33% | 37,447 | 43,381 | 16% |
| Dishwashers | 713 | 369 | -48% | 183 | 95 | -48% | 37,447 | 43,381 | 16% |

[1]Price: Shipment weighted retail sales price. **Sources:** AHAM Fact Book and Appliance Magazine.
[2]Operating Cost: Annual electricity price times electricity consumption. **Source:** AHAM Fact Book.
[3]Income: Mean Household income. **Source:** U.S. Census.

## 10A.4 REGRESSION ANALYSIS OF VARIABLES AFFECTING APPLIANCE SHIPMENTS

Little data is available for estimating the impact of economic variables on the demand for appliances. Industry operating cost data is incomplete—appliance energy use data is available for only 12 years of the 1980-2002 study period. Industry price data is also incomplete—available for only 8 years of the study period for each of the appliances.

The lack of data suggests that regression analysis can at best evaluate broad data trends, utilizing relatively few explanatory variables. This section begins by describing broad trends apparent in the economic and physical household data sets and then specifies a simple regression model to measure these trends, making assumptions to minimize the number of explanatory variables. Finally, results are presented of the regression analysis and the estimate of the price

elasticity of demand for appliances. In this section (specifically section 9A.4.5), DOE also presents the results of regression analysis performed with more complex models, and used to test assumptions made to specify the simple model. These results support the simple model specification, and estimates of the price elasticity of appliance demand measured with that model.

### 10A.4.1 Broad Trends

In this section DOE reviews trends in the physical household and economic data sets and posit a simple approach for estimating the price elasticity of appliance demand. As noted above, the physical household variables (starts and appliance replacements), explain most of the variability in appliance shipments over the period.[b] DOE assumes the rest of the variability in shipments (referred to as "residual shipments") is explained by economic variables, and present a tabular method for measuring price elasticities described below.

To illustrate this tabular approach, DOE defines two new variables—residual shipments and total price. Residual shipments are defined as the difference between shipments and physical household demand (starts plus replacements). Total price, represented by the following equation, is defined as appliance price plus the present value of lifetime appliance operating cost:[c]

$$\boldsymbol{TP} = \boldsymbol{PP} + \boldsymbol{PVOC}$$

where:

*TP* = Total price,
*PP* = Appliance purchase price, and
*PVOC* = Present value of operating cost.

Over the study period, residual shipments increase 30 percent for refrigerators, 19 percent for clothes washers, and 23 percent for dishwashers in proportion to total shipments. At the same time, total prices decline 47 percent, 45 percent and 48 percent for refrigerators, clothes washers, and dishwashers, respectively. Assuming that total price explains the entire change in per household appliance usage, a rough estimate is calculated of the total price elasticity of demand equal to -0.48 for refrigerators, -0.32 for clothes washers and -0.37 for dishwashers (Table 9A.4.1).

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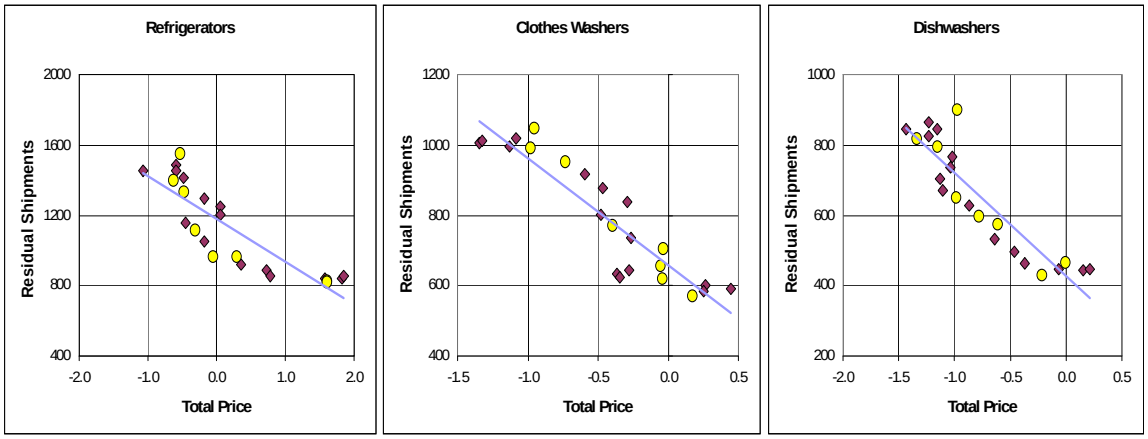
[b] A log regression of the form: Shipments = a + b • Housing Starts + c • Retirements, indicates that these two variables explain 89 percent of the variation in refrigerator shipments, 97 percent of the variation in clothes washer shipments, and 97 percent of the variation in dishwasher shipments.

[c] Present value operating cost is calculated assuming a 19 year operating life for refrigerators, 14 year operating life for clothes washers, and a 12 year operating life for dishwashers. A 37 percent discount rate is used to sum annual operating costs into a present value operating cost.

**Table 10A.4.1 Simple Estimate of Total Price Elasticity of Demand**

| | Residual Shipments (millions) | | | | Total Price (199$) | | | |
|---|---|---|---|---|---|---|---|---|
| **Appliance** | **1980** | **2002** | **Difference** | **Change** | **1980** | **2002** | **Change** | **Elasticity** |
| Refrigerators | -0.5 | 1.6 | 2.1 | 30% | 1541 | 820 | -61% | -0.48 |
| Clothes Washers | -1.0 | 0.2 | 1.1 | 19% | 1042 | 567 | -59% | -0.32 |
| Dishwashers | -1.0 | -0.01 | 1.0 | 23% | 896 | 464 | -64% | -0.37 |

The negative correlation between total price and residual shipments suggested by these negative price elasticities is illustrated in a graph of residual shipments on the y-axis and total price on the x-axis (Figure 9A.4.1).




Yellow points are observed price data; red points are interpolated price data.

**Figure 10A.4.1 Residual Shipments and Appliance Price**

Household income rose during the study period, making it easier for households to purchase appliances. Assuming that a rise in income has a similar impact on shipments as a decline in price, the impact of income is incorporated by defining a third variable, termed *relative* price, calculated as total price divided by household income and represented by the following equation:[d]

$$RP = \frac{TP}{Income}$$

where:

*RP* = Relative price,
*TP* = Total price, and
*Income* = Household income.

[d] Recall that the income elasticity of demand cited in the literature review is 0.50 and the price elasticity of demand cited in the review averages -0.35. This suggests that combining the effects of income and price will yield an elasticity less negative than price elasticity alone.

The percent decline in *relative* price for the three appliances divided by the percent decline in residual shipments suggests a rough estimate of *relative* price elasticity equal to -0.40 for refrigerators, -0.26 for clothes washers and -0.30 for dishwashers (Table 9A.4.2).

**Table 10A.4.2 Tabular Estimate of Relative Price Elasticity of Appliance Demand**

| | Residual Shipments (millions) | | | Relative Price (1999$) | | | Elasticity |
|---|---|---|---|---|---|---|---|
| **Appliance** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** | |
| Refrigerators | -0.532 | 1.597 | 30% | 0.041 | 0.019 | -74% | -0.40 |
| Clothes Washers | -0.953 | 0.174 | 19% | 0.028 | 0.013 | -72% | -0.26 |
| Dishwashers | -0.974 | -0.005 | 23% | 0.024 | 0.011 | -76% | -0.30 |

### 10A.4.2 Model Specification

The limited price data suggests using a simple regression model to estimate the impact of economic variables on shipments, using few explanatory variables. The following equation chosen for this analysis includes one physical household variable (starts plus replacements) and one *relative* price variable (the sum of purchase price plus operating cost, divided by income).

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor} \qquad \textbf{Eq. 9A.1}$$

where:

*Ship* = Quantity of appliance sold,
*RP* = Relative price,
*Starts* = Number of new homes, and
*Rplc* = Number of appliances at the end of their operating life.

The natural logs are taken of all variables so that the estimated coefficients for each variable in the model may be interpreted as the percent change in shipments associated with the percent change in the variable. Thus, the coefficient b in this model is interpreted as the *relative* price elasticity of demand for the three appliances.

The following combined regression equation is used to estimate an average price elasticity of demand across the three appliances, using pooled data in a single regression. A combined regression specification is justified, given limited data availability and similarity in price and shipment behavior across appliances (see Figure 9A.4.1). Thus, the model represented by the combined regression equation is considered the basic model in DOE's analysis of appliance shipments.

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor + d \times CW + e \times DW} \qquad \textbf{Eq. 9A.2}$$

where:

*CW* = Quantity of clothes washers sold, and
*DW* = Quantify of dishwashers sold.

### 10A.4.3 Model Discussion

The most important assumption used to specify this model is that changes in economic variables over the study period—income, price, and operating cost—are responsible for all observed growth in residual appliance shipments. In other words, DOE assumes other possible explanations, such as changing consumer preferences and increases in the quality of appliances—had no impact. This assumption seems unlikely but without additional data, the impact of this assumption on the price elasticity of demand cannot be measured. DOE effectively assumes that changes in consumer preferences and appliance characteristics, while affecting which specific models are purchased, have relatively little impact on the total number of appliances purchased in a year.

Three additional assumptions used to specify this model deserve comment. The *relative* price variable is specified in the model, assuming that (1) the correct implicit discount rate is used to combine appliance price and operating cost and that (2) rising income has the same impact on shipments as falling total price. The "starts + replacements" variable is specified, assuming (3) that starts and replacements have similar impacts on shipments.

To investigate the first assumption about discount rates, DOE calculated "present value operating cost" using a 20 percent implicit discount rate and performed a second regression analysis based on the models described in equations. 9A.1 and 9A.2. The results of this analysis, presented in section 9A.4.5, indicate that the elasticity of *relative* price is relatively insensitive to changes in the discount rate.

To investigate the second and third assumptions, DOE specified a regression model separating income from total price and replacements from starts, thus adding two additional explanatory variables to the basic model as shown in the following equation:

$$\boldsymbol{Ship} = \boldsymbol{a} + \boldsymbol{b} \times \boldsymbol{TP} + \boldsymbol{c} \times \boldsymbol{Income} + \boldsymbol{d} \times \boldsymbol{Start} + \boldsymbol{e} \times \boldsymbol{Rplc} + \boldsymbol{f} \times \boldsymbol{CW} + \boldsymbol{g} \times \boldsymbol{DW} \qquad \textbf{Eq. 9A.3}$$

The results of the regression analysis of this model are also presented in section 9A.4.5. These results suggest that the elasticity of total price (coefficient b) is relatively insensitive to changes in the treatment of income and "starts + replacements" in the model.

### 10A.4.4 Analysis Results

#### 10A.4.4.1 Individual Appliance Model

The individual appliance regression equations are specified as followed (as shown earlier as Eq. 9A.1):

$$\boldsymbol{Ship} = \boldsymbol{a} + \boldsymbol{b} \times \boldsymbol{RP} + \boldsymbol{c} \times \lfloor \boldsymbol{Starts} + \boldsymbol{Rplc} \rfloor$$

In regression analysis of this model, the elasticity of *relative* price (b) is estimated to be

-0.40 for refrigerators, -0.31 for clothes washers and -0.32 for dishwashers (Table 9A.4.3), averaging -0.35. These elasticities are similar to those reported in the literature survey for appliances (Table 9A.2.1). They are remarkably similar to the price elasticity calculated using a tabular approach presented above (Table 9A.4.2).

The estimated coefficient associated with the "starts + replacements" variable is close to one. A coefficient equal to one for this variable would imply that shipments increase in direct proportion to an increase in "starts + replacements", holding economic variables constant. The high R squared values (above 95) and t statistics (above 5) in the results provide a measure of confidence in this analysis, despite the very small data set.

**Table 10A.4.3 Individual Appliance Model Results**

| | Refrigerator | | Clothes Washer | | Dishwasher | |
|---|---|---|---|---|---|---|
| **Variable** | **Coefficient** | **t-stat** | **Coefficient** | **t-stat** | **Coefficient** | **t-stat** |
| Intercept | -1.51 | -7.26 | -1.47 | -8.23 | -2.08 | -16.78 |
| Relative Price | -0.40 | -6.60 | -0.31 | -5.69 | -0.32 | -7.03 |
| Starts + Replacements | 1.05 | 5.90 | 1.08 | 6.41 | 1.35 | 11.46 |
| $R^2$ | 0.954 | | 0.954 | | 0.975 | |
| Observations | 23 | | 23 | | 23 | |

### 10A.4.4.2 Combined Appliance Model

The combined appliance regression equation is specified as follows (as shown earlier as Eq. 9A.2):

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor + d \times CW + e \times DW}$$

This regression analysis indicates that the model fits the existing shipments data well (high R squared) and that the variables included in the model are statistically significant (Table 9A.4.4). The elasticity of *relative* price estimated with this model is -0.34, close to the average value estimated in the individual appliance models (-0.35). It is also similar to elasticity estimates reported in the literature survey and calculated using the tabular approach above.

**Table 10A.4.4 Combined Appliance Model Result**

| **Variable** | **Coefficient** | **t-stat** |
|---|---|---|
| Intercept | -1.60 | -15.54 |
| Relative Price | -0.34 | -10.74 |
| Starts + Replacements | 1.21 | 13.95 |
| CW | -0.20 | -9.04 |
| DW | -0.32 | -6.58 |
| $R^2$ | 0.983 | |
| Observations | 69 | |

### 10A.4.5 Additional Regression Specifications and Results

As described above in section 9A.4.3, DOE used three assumptions to specify its appliance models. The first is that the implicit price variable in the basic regression model is specified using a 37 percent implicit discount rate, to aggregate appliance price and operating cost. The second states that the implicit price variable is defined assuming that rising income has the same impact on shipments as falling total price. The third states that the "starts + replacements" variable is defined assuming that housing starts have a similar impact on shipments as appliance replacements.

#### 10A.4.5.1 Lower Consumer Discount Rate

To investigate the first assumption about discount rates, DOE calculated "present value operating cost" using a 20 percent implicit discount rate and performed a second regression analysis based on the models described in equations 9A.1 and 9A.2. The estimated coefficient associated with the *relative* price variable in these regressions is almost identical to the coefficients estimated for same variable reported above using a 37 percent implicit discount rate. The elasticity of *relative* price calculated using a 20 percent discount rate is -0.33 in the combined regression and averages -0.35 for the three appliances (Table 9A.4.5). The elasticity of price calculated using a 37 percent discount rate is -0.34 in the combined regression and averages -0.35 for the three appliances. DOE concludes from this analysis that the elasticity of *relative* price is relatively insensitive to changes in the discount rate.

**Table 10A.4.5 Combined and Individual Results, 20 percent discount rate**

| Three Appliances<br>Variable | Coefficient | t-Stat |
|---|---|---|
| Intercept | -1.53 | -14.61 |
| Total Price / Income | -0.33 | -10.69 |
| Starts + Retirements | 1.20 | 13.65 |
| CW | -0.18 | -8.69 |
| DW | -0.32 | -6.57 |
| | | |
| $R^2$ | 0.982 | |
| Observations | 69 | |

| | Refrigerator | | Clothes Washers | | Dishwasher | |
|---|---|---|---|---|---|---|
| Variable | Coefficient | t-Stat | Coefficient | t-Stat | Coefficient | t-Stat |
| Intercept | -1.36 | -6.26 | -1.41 | -7.49 | -2.04 | -17.23 |
| Total Price / Income | -0.38 | -6.50 | -0.32 | -5.29 | -0.33 | -7.30 |
| Starts + Retirements | 1.04 | 5.73 | 1.06 | 5.83 | 1.34 | 11.64 |
| | | | | | | |
| $R^2$ | | 0.953 | | 0.950 | | 0.977 |
| Observations | | 23 | | 23 | | 23 |

#### 10A.4.5.2 Disaggregated Variables

To investigate the second and third assumptions, DOE constructed a regression model separating income from total price and replacements from starts, thus adding two additional explanatory variables to the basic model (as shown earlier as Eq. 9A.3).

$$Ship = a + b \times TP + c \times Income + d \times Start + e \times Rplc + f \times CW + g \times DW$$

The estimated coefficient associated with the total price variable in these regressions is almost identical to the coefficients estimated for the *relative* price variable reported above. The elasticity of total price in the above equation is -0.36 in the combined appliance regression and averages -0.35 for the three appliances (Table 9A.4.6). The elasticity of *relative* price based on the model described in equation 9A.2 is -0.34 in the combined regression (Table 9A.4.4) and averages -0.35 across the individual appliances (Table 9A.4.3). DOE concludes that the price elasticity calculated in this analysis is relatively insensitive to the specification of household income and "starts + replacements" variables in the model.

**Table 10A.4.6 Disaggregated Regression Results, 37 percent discount rate**

| Three Appliances | | |
|---|---|---|
| **Variable** | **Coefficient** | **t-Stat** |
| Intercept | -2.92 | -1.26 |
| Income | 0.58 | 2.92 |
| Total Price | -0.36 | -7.06 |
| Housing Starts | 0.44 | 10.02 |
| Retirements | 0.62 | 8.12 |
| CW | -0.24 | -9.25 |
| DW | -0.46 | -7.68 |
| | | |
| $R^2$ | | 0.985 |
| Observations | | 69 |

| | Refrigerator | | Clothes Washers | | Dishwasher | |
|---|---|---|---|---|---|---|
| **Variable** | **Coefficient** | **t-Stat** | **Coefficient** | **t-Stat** | **Coefficient** | **t-Stat** |
| Intercept | -6.19 | -2.24 | -6.64 | -1.63 | 1.00 | 0.23 |
| Income | 0.89 | 3.80 | 0.87 | 2.31 | 0.20 | 0.52 |
| Total Price | -0.35 | -5.48 | -0.27 | -2.51 | -0.43 | -5.18 |
| Housing Starts | 0.41 | 7.38 | 0.25 | 3.29 | 0.62 | 8.24 |
| Retirements | 0.56 | 6.06 | 0.56 | 2.09 | 0.65 | 5.86 |
| | | | | | | |
| $R^2$ | | 0.984 | | 0.958 | | 0.979 |
| Observations | | 23 | | 23 | | 23 |

## 10A.5 LONG RUN IMPACTS

As noted above in Table 9A.2.1 in section 9A.2, the literature review provides price elasticities over short and long time periods, also referred to as short run and long run price elasticities. As noted in the first two rows of Table 9A.2.1, one source (i.e., Hymans) shows that the price elasticity of demand is significantly different over the short run and long run for automobiles.[1] Because DOE's forecasts of shipments and national impacts due to standards is over a 30-year time period, consideration must be given as to how the *relative* price elasticity is affected once a new standard takes effect.

DOE considers the *relative* price elasticities determined above in section 9A.4 to be short run elastcities. DOE was unable to identify sources specific to household durable goods, such as appliances, to indicate how short run and long run price elasticities differ. Therefore, to estimate how the *relative* price elasticity changes over time, DOE relied on the Hymans study pertaining to automobiles. Based on the Hymans study, Table 9A.5.1 shows how the automobile price

elasticity of demand changes in the years following a purchase price change. With increasing years after the price change, the price elasticity becomes more inelastic until it reaches a terminal value around the tenth year after the price change.

**Table 10A.5.1 Change in Price Elasticity of Demand for Automobiles following a Purchase Price Change**

| | Years Following Price Change | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **5** | **10** | **20** |
| Price Elasticity of Demand | -1.20 | -0.93 | -0.75 | -0.55 | -0.42 | -0.40 |
| Relative Change in Elasticity to 1st year | 1.00 | 0.78 | 0.63 | 0.46 | 0.35 | 0.33 |

**Source:** Hymans, 1971.

Based on the relative change in the automobile price elasticity of demand shown in Table 9A.5.1, DOE developed a time series of *relative* price elasticities for home appliances. Table 9A.5.2 presents the time series.

**Table 10A.5.2 Change in *Relative* Price Elasticity for Home Appliances following a Purchase Price Change**

| | Years Following Price Change | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **5** | **10** | **20** |
| Relative Change in Elasticity to 1st year | 1.00 | 0.78 | 0.63 | 0.46 | 0.35 | 0.33 |
| *Relative* Price Elasticity | -0.34 | -0.26 | -0.21 | -0.16 | -0.12 | -0.11 |

## 10A.6 SUMMARY

This appendix describes the results of a literature search, tabular analysis and regression analysis of the impact of price and other variables on appliance shipments. In the literature, DOE finds only a few studies of appliance markets that are relevant to this analysis, and no studies using time series price and shipments data after 1980. The information that can be summarized from the literature, suggests that the demand for appliances is price inelastic. Other information in the literature suggests that appliances are a normal good, such that rising incomes increase the demand for appliances. Finally, the literature suggests that consumers use relatively high implicit discount rates, when comparing appliance prices and appliance operating costs.

There is not enough price and operating cost data available to perform complex analysis of dynamic changes in the appliance market. In this analysis, DOE uses data available for refrigerators, clothes washers and dishwashers to evaluate broad market trends and to perform simple regression analysis.

These data indicate that there has been a rise in appliance shipments and a decline in appliance price and operating cost over the period. Household income has also risen during this time. To simplify the analysis, DOE combined the available economic information into one

variable, termed *relative* price, and used this variable in a tabular analysis of market trends, and a regression analysis.

DOE's tabular analysis of trends in the number of appliances per household suggests that the price elasticity of demand for the three appliances is inelastic. Our regression analysis of these same variables suggests that the *relative* price elasticity of demand is -0.34. The price elasticity is consistent with estimates in the literature. Nevertheless, DOE stresses that the measure is based on a small data set, using very simple statistical analysis. More important, the measure is based on an assumption that economic variables, including price, income and operating costs, explain most of the trend in appliances per household in the United States since 1980. Changes in appliance quality and consumer preferences may have occurred during this period, but they are not accounted for in this analysis.

## 10A.7 DATA USED IN THE ANALYSIS

- **Appliance Shipments:** Shipments are defined as the annual number of units shipped in millions. These data were collected from the Association of Home Appliance Manufacturers (AHAM)[8] and Appliance Magazine[9] as annual values for each year, 1980–2002. AHAM was used for the period 1989–2002 while Appliance Magazine was used for the period 1980–1988.

- **Appliance Price:** Price is defined as the shipments weighted retail sales price of the unit in 1999 dollars. Price values for 1980, 1985, 1986, 1991, 1993, 1994, 1998, and 2002 were collected from AHAM Fact Books.[10] Price values for other years were interpolated from these eight years of data.

- **Housing Starts:** Housing starts data were collected from U.S. Census construction statistics (C25 reports) as annual values for each year, 1980–2002.[11]

- **Replacements:** Retirement-driven replacements are estimated with the assumption that some fraction of sales arise from consumers replacing equipment at the end of its useful life. Since each appliance has a different expected lifespan (19 years for refrigerators[12], 14 years for clothes washers[13], 12 years for dishwashers[14]), replacements are calculated differently for each appliance type. Replacements are estimated as the average of shipments 14–24 years previous for refrigerators, 9–19 years previous for clothes washers, and 7–17 years previous for dishwashers. Historical shipments data were collected from AHAM and Appliance Magazine.

- **Annual Electricity Consumption:** Electricity Use (UEC) is defined as the energy consumption of the unit in kilowatt-hours. Electricity consumption is dependent on appliance capacity and efficiency. These data were provided by AHAM for 1980, 1990–1997 and 1999–2002.[15] Data were interpolated in the years for which data were not available.

- **Operating Cost:** Operating Cost is the present value of the electricity consumption of an appliance over its expected lifespan. The lifespans of refrigerators, clothes washers and dishwashers are assumed to be 19, 14, and 12 years respectively. Discount rates of 20 percent[6] and 37 percent[16] were used, producing similar estimates of price elasticity. A study by Hausman recommended a discount rate of "about 20 percent" in its introduction, and presented results ranging from 24.1 percent to 29 percent based on his calculations for room air conditioners. A study by Train suggests a range of implicit discount rates averaging 35 percent for appliances.

- **Income:** Median annual household income in 2003 dollars. This data was collected for each year, 1980–2002, from Table H-6 of the U.S. Census.[17]

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